Use the following data wherever necessary :

Charge of electron $e = 1.6 \times 10^{-19}$ C

The following list of formulae may be found useful :

Law of radioactive decay $N = N_0 e^{-kt}$

Half-life and decay constant $t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$

Activity and the number of undecayed nuclei $A = kN$

Part A :

The following questions marked with { } are the past DSE examination questions.

The questions marked with {SP} are the Sample Paper questions.

The questions marked with {PP} are the Practice Paper questions.

The number inside the brackets represents the year of the DSE examination.

M1. On which of the following does the activity of a radioactive source depend ?
{SP}
(1) the nature of the nuclear radiation emitted by the source
(2) the half-life of the source
(3) the number of active nuclei in the source

A. (1) only
B. (2) only
C. (1) & (2) only
D. (2) & (3) only

M2. Different absorbers are placed in turn between a radioactive source and a Geiger-Muller tube. Three readings are taken for each absorber. The following data are obtained :
{SP}

Absorber	Count rate / s^{-1}		
–	200	205	198
Paper	197	202	206
5 mm aluminium	112	108	111
25 mm lead	60	62	58
50 mm lead	34	36	34

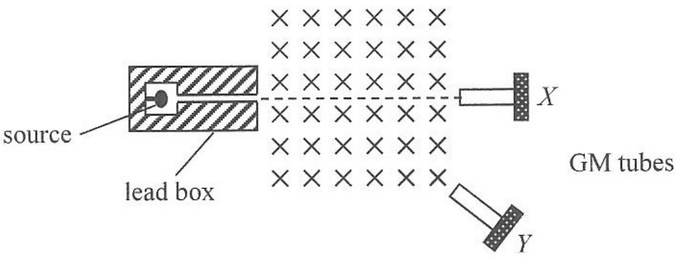
What type(s) of radiation does the source emit ?

A. β only
B. γ only
C. β and γ only
D. α, β and γ

M3. Which of the following statements about α and β particles is/are correct ?
{PP}
(1) The mass of an α particle is greater than that of a β particle.
(2) α particles have a stronger penetrating power than β particles.
(3) An α source can discharge a positively charged metal sphere nearby.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

M4.
{PP}



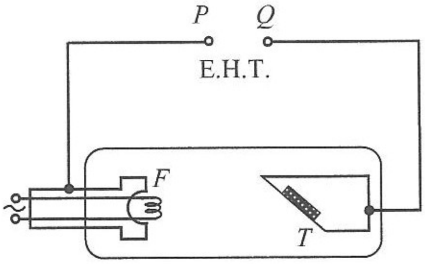
A radioactive source is placed in front of a uniform magnetic field pointing into the paper as shown above. The count rates recorded by the GM tubes at X and Y are 101 counts per minute and 400 counts per minute respectively. Which of the following deductions must be correct ?

A. The source does not emit α radiations.
B. The source emits β radiations.
C. The source emits γ radiations.
D. The background count rate is about 100 counts per minute.

M5. A certain radioactive isotope X has a half-life of 20 hours. After a time interval of 10 hours, what is the approximate
{12} fraction (f) of a sample of the radioactive isotope X remaining ?

A. $\frac{1}{4} \leq f \leq \frac{1}{2}$
B. $f = \frac{1}{2}$
C. $\frac{3}{4} > f > \frac{1}{2}$
D. $f > \frac{3}{4}$

M6. The figure shows a schematic diagram of an X-ray tube in which the
{12} filament F and the metal target T are connected to terminals P and Q of an E.H.T. Which statement is correct ?



A. P is the positive terminal and X-rays are emitted from T.
B. P is the positive terminal and X-rays are emitted from F.
C. Q is the positive terminal and X-rays are emitted from T.
D. Q is the positive terminal and X-rays are emitted from F.

M7. Polonium-210 is a pure α-emitter with a half-life of 140 days and it will decay into lead, which is stable. Initially there is a
{13} sample containing 420 mg of pure polonium-210. Estimate the mass of polonium-210 left after 70 days.

A. 315 mg
B. 297 mg
C. 210 mg
D. 105 mg

M8. A GM counter is placed close to and in front of a radioactive source which emits both α and γ radiations. The count rate
{14} recorded is 450 counts per minute while the background count rate is 50 counts per minute. Three different materials are placed in turn between the source and the counter. The following results are obtained.

Material	Recorded count rate / counts per minute
(Nil)	450
cardboard	x
1 mm of aluminium	y
2 mm of lead	z

Which of the following is the most suitable set of values for x, y and z ?

	x	y	z
A.	300	300	100
B.	300	100	50
C.	100	100	0
D.	100	50	50

M9. Some factories make use of radioactive source for manufacturing. Workers are required to wear clothes with film badges to
{15} measure the dosage of radiation received over a period of time. Which type of radiation below CANNOT be monitored by the film badges ?

A. α-radiation
B. β-radiation
C. γ-radiation
D. X-rays

Part B :

The following questions marked with ( ) are the past HKCE questions.

The number inside the brackets represents the year of the examination.

M10. In a β decay, element X, having a half-life of 3 days, decays into a stable element Y. If the initial mass of X is 4 g, what will
(80) be the masses of X and Y after 6 days ?

	Mass of X	Mass of Y
A.	0 g	4 g
B.	1 g	3 g
C.	2 g	2 g
D.	3 g	1 g

M11. If the three kinds of radiations α, β and γ are arranged in ascending order of their ionization power, their order is
(81) A. α, β, γ
B. α, γ, β
C. β, α, γ
D. γ, β, α

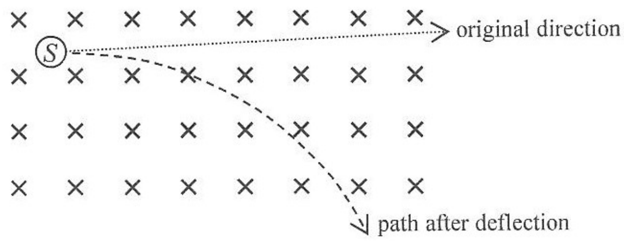
M12. A radioactive substance has a half-life of 10 minutes. Which of the following statements is/are correct ?
(82) (1) All the atoms of the radioactive substance will split into 4 equal parts in 5 minutes.
(2) All the atoms of the radioactive substance will decay completely in 20 minutes.
(3) All the atoms of the radioactive substance will decay within 10 minutes.

A. (1) only
B. (2) only
C. (3) only
D. None of them

M13. The half-life of a radioactive substance is 8 hours. Its initial mass is 3 g. Find the amount of the radioactive substance
(83) remaining unchanged after 24 hours.

A. 0.375 g
B. 0.75 g
C. 1 g
D. 2 g

M14. S is a radioactive source which emits radiation as it decays.
(84) If all the radiation emitted is bent by a magnetic field in the direction shown, then the radiation consists of



A. α and γ only
B. β and γ only
C. α only
D. β only

M15. The corrected count rate of a sample of radioactive material was measured on the first day of each month. The readings on
(85) July 1 and September 1 are 0.8 and 0.2 counts per second respectively. What is the half-life of the radioactive material ?

A. 7 days
B. 16 days
C. 31 days
D. 46 days

M16. The speeds of X-rays, γ rays and β rays in air are denoted by v_X, v_γ and v_β respectively. Which of the following is true ?
(86) A. $v_X > v_\gamma > v_\beta$
B. $v_X < v_\gamma < v_\beta$
C. $v_X = v_\gamma = v_\beta$
D. $v_X = v_\gamma > v_\beta$

M17. Which of the following about α radiation is/are correct ?
(87)
(1) The mass of an α particle is about four times that of a hydrogen atom.
(2) It has a stronger ionizing power than β radiation.
(3) It has a greater penetration power than γ radiation.

A. (1) only
B. (2) only
C. (1) & (2) only
D. (2) & (3) only

M18. Which of the following descriptions of the half-life of a sample of radioactive isotope is/are correct ? The half life is
(87)
(1) the time taken for the mass of the sample to fall to half of its initial value.
(2) the time taken for the activity of the sample to fall to half of its initial value.
(3) half of the time taken for the sample to decay completely.

A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

M19. The activity of a radioactive source falls to $\frac{1}{8}$ of its original value in 24 minutes. The half-life of the source is
(88) A. 3 min.
B. 6 min.
C. 8 min.
D. 72 min.

M20. A radioactive source has a half-life of 22 years. After 66 years, what fraction of the source remains undecayed ?

(89) A. $\frac{1}{3}$

B. $\frac{1}{6}$

C. $\frac{1}{8}$

D. $\frac{1}{9}$

M21. In an experiment to measure the half-life of a radioactive isotope in a place where the background count rate is 20 counts per
(90) minute, the following results are recorded :

Time / minute	0	2	4	6	8	10	12
Total count rate / counts per minute	116	96	80	69	58	50	44

The half-life is about

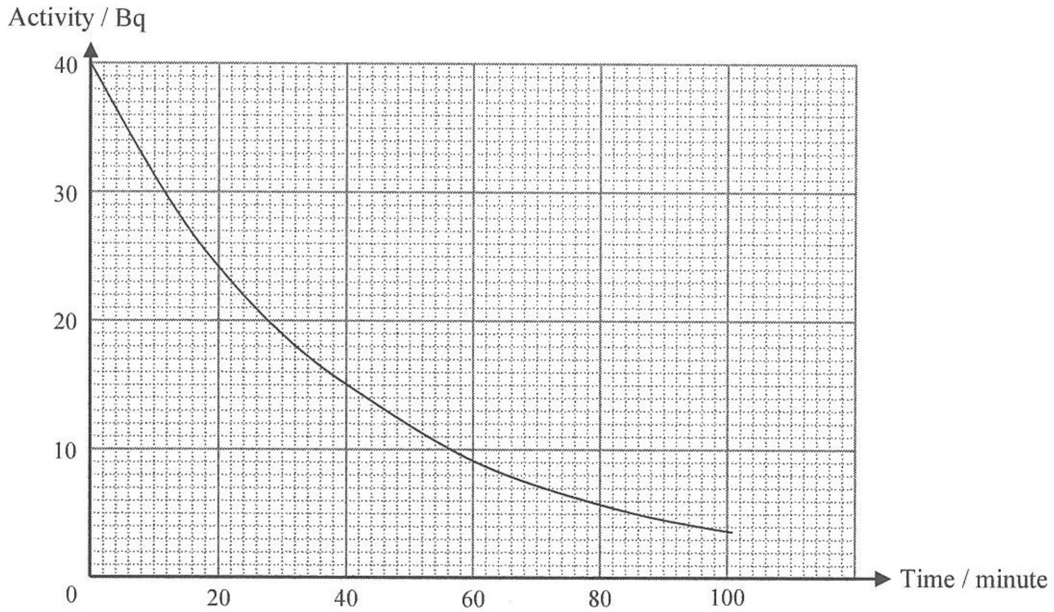
A. 4 min.

B. 6 min.

C. 8 min.

D. 10 min.

M22.
(91)



The activity of a radioactive source is recorded on a graph as shown above. What is the half-life of the source ?

A. 20 min.

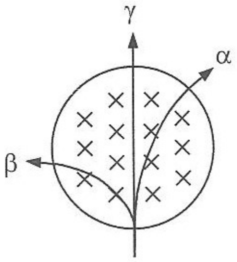
B. 24 min.

C. 28 min.

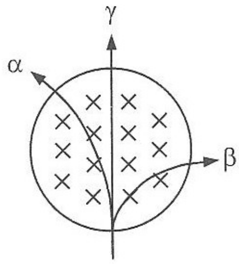
D. 32 min.

M23. Which of the following diagrams correctly shows the deflections of α, β and γ rays in a uniform magnetic field pointing into
(92) the paper ?

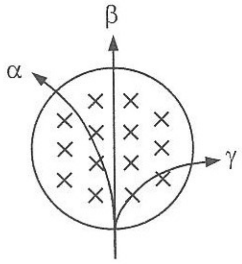
A.



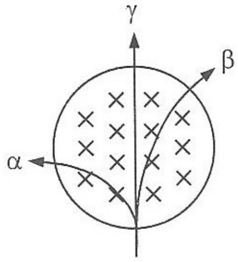
B.



C.

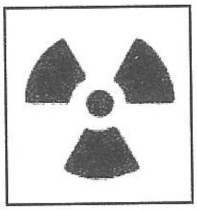


D.

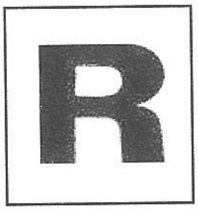


M24. Which of the following signs is used to indicate radioactive material ?
(93) A.

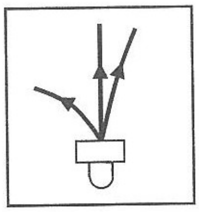
B.



C.



D.



M25. Arrange α, β and γ radiation in ascending order of their ionizing powers :
(94) A. α , β , γ
B. β , γ , α
C. γ , α , β
D. γ , β , α

M26. The activity of a radioactive source drops from 640 Bq to 40 Bq in 2 hours. Find the half-life of the source.
(94) A. 7.5 min.
B. 15 min.
C. 24 min.
D. 30 min.

M27. Which of the following cannot travel through a vacuum ?
(95) A. β particles
B. Infra-red
C. Microwaves
D. Ultrasonics

M28. Which of the following statements about X-rays is/are correct ?
(95) (1) X-rays consist of fast moving electrons.
(2) X-rays can blacken photographic films.
(3) X-rays can be used to detect weapons hidden in luggage.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

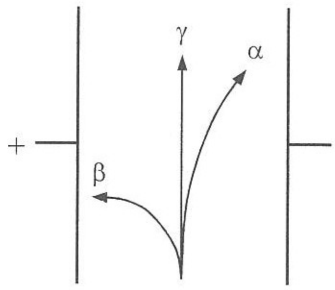
M29. Which of the following can be deflected by both an electric field and a magnetic field ?
(96) (1) α particles
(2) β particles
(3) γ rays

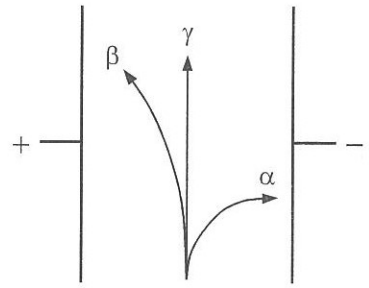
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

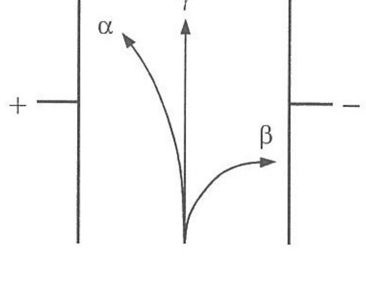
M30. The activity of a radioactive isotope falls to $\frac{1}{16}$ of its initial value in one hour. Find the half-life of the isotope.
(96) A. 3.75 minutes
B. 7.5 minutes
C. 10 minutes
D. 15 minutes

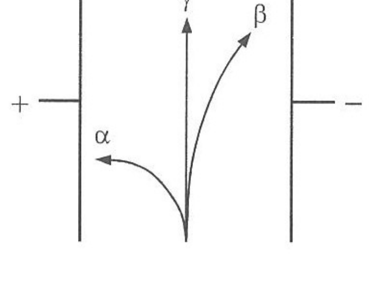
M31. Which of the following statements about β particles is **incorrect** ?
(97) A. β particles can be stopped by a piece of paper.
B. β particles can be deflected by a magnetic field.
C. β particles can blacken photographic films.
D. β particles can travel through a vacuum.

M32. Which of the following diagrams correctly shows the directions in which α, β and γ radiations are deflected in a uniform
(98) electric field produced by two charged metal plates ?

A.


B.


C.


D.


M33. Which of the following statements about α particles is **incorrect** ?
(99) A. α particles can be stopped by a piece of paper.
B. α particles can blacken photographic films.
C. α particles have a range of several centimetres in air.
D. α particles cannot travel through a vacuum.

M34. An insulated metal sphere carries positive charges. Which of the following will discharge the sphere ?
(99) (1) bringing an alpha source near the sphere
(2) touching the sphere momentarily with a finger
(3) bringing a negatively charged metal rod near the sphere (but without touching it)
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M35. The background count rate recorded by a Geiger-Muller counter is 80 counts per minute. When a radioactive source is
(99) placed closely in front of the Geiger-Muller tube, the count rate recorded is 560 counts per minute. After 6 hours, the count rate drops to 140 counts per minute. Find the half-life of the source.
A. 45 minutes
B. 1 hour
C. 1 hour 30 minutes
D. 2 hours

M36. Which of the following statements about α particles and γ rays is correct ?
(00) A. Both of them are transverse waves.
B. Both of them can be deflected by a magnetic field.
C. Both of them have strong ionizing power.
D. Both of them can travel through a vacuum.

M37. Which one of the following is **not** a safety precautions for handling radioactive sources ?
(00) A. Users should not eat or drink when handling radioactive sources.
B. Users should wear gloves for handling radioactive sources.
C. Radioactive sources should not be held close to the eye for visual examination.
D. Radioactive sources should be stored in wooden boxes after use.

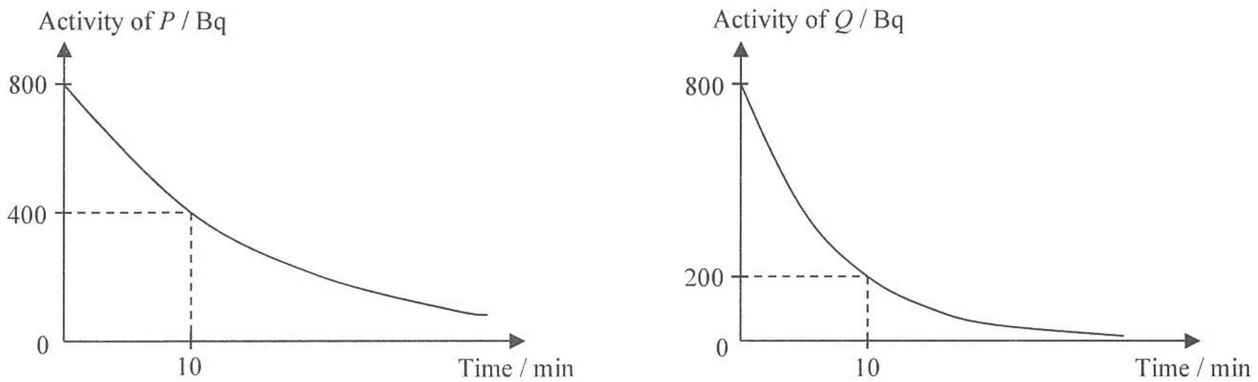
M38. The initial activity of a radioactive isotope is 2000 Bq. After 4 hours, the activity of the isotope drops to 125 Bq.
(01) Find the half-life of the isotope.
A. 15 minutes
B. 30 minutes
C. 48 minutes
D. 60 minutes

M39. Which of the following particles **cannot** be deflected by a magnetic field ?
(02) A. α-particles
B. β-particles
C. neutrons
D. protons

M40. Which of the following statements about α particles and γ rays is/are correct ?
(03)
(1) They can both be deflected by a magnetic field.
(2) α particles have a stronger ionizing power than γ rays.
(3) They are emitted with almost the same speed in radioactive decay.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

M41.
(03)



The figures above show the variation of the activities of two radioactive sources P and Q with time. Find the ratio of the half-life of P to that of Q.

A. 1 : 1
B. 1 : 2
C. 2 : 1
D. 4 : 1

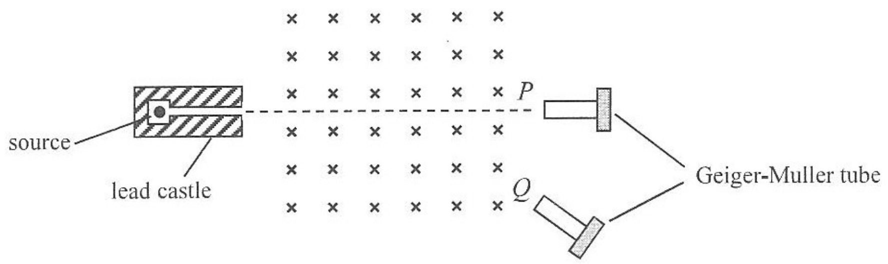
M42. Different absorbers are placed in turn between a radioactive source and a Geiger-Muller tube. Three readings are taken for
(04) each absorber. The following data are obtained :

Absorber	Count rate / s^{-1}		
–	200	205	198
Paper	197	202	206
5 mm aluminium	112	108	111
25 mm lead	60	62	58
50 mm lead	34	36	34

What type(s) of radiation does the source emit ?

A. β only
B. γ only
C. β and γ only
D. α, β and γ

M43.
(05)

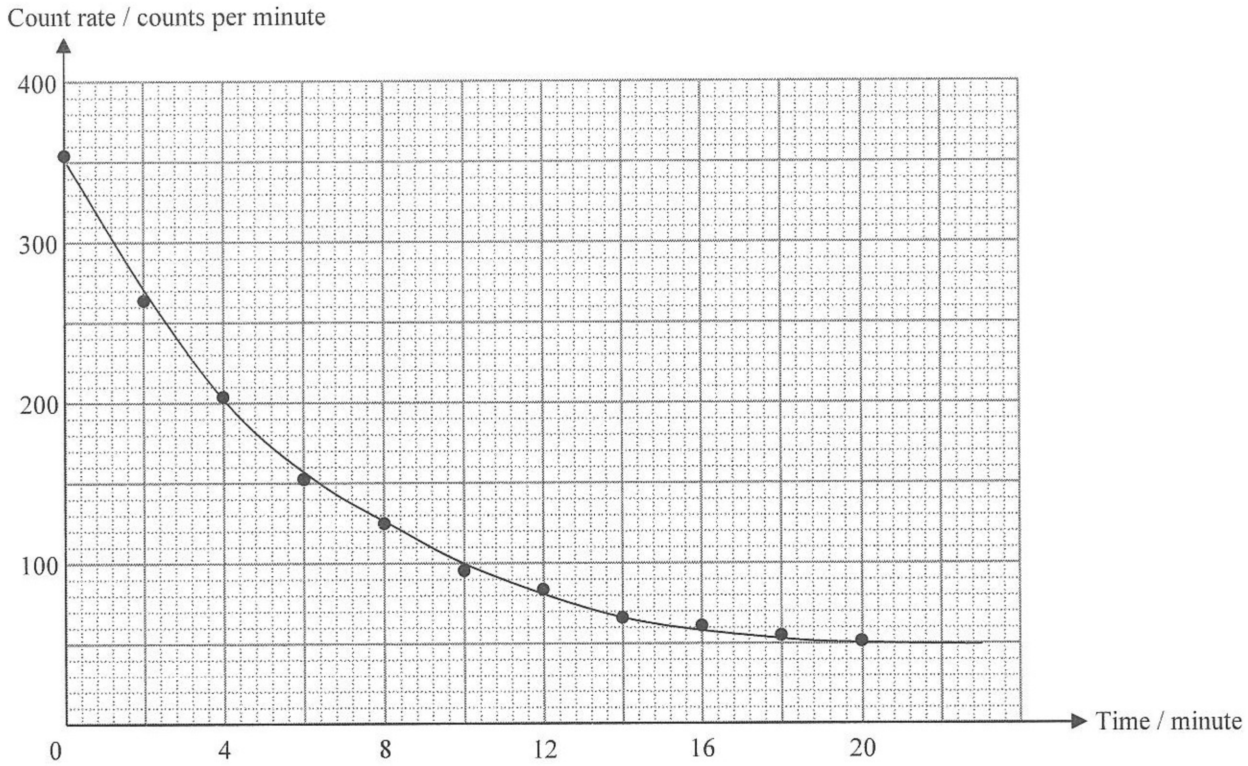


A radioactive source is placed in front of a uniform magnetic field pointing into the paper as shown above. If a high count rate is recorded at positions P and Q, what kinds of radiation have been detected ?

	P	Q
A.	γ	α
B.	γ	β
C.	β	α
D.	β	γ

M44. A radioisotope X has a half-life of 2 days while another radioisotope Y has a half-life of 1 day. Initially there are N undecayed atoms of X and 8 N undecayed atoms of Y. After how many days will X and Y have the same number of undecayed atoms ?
(06)
A. 3 days
B. 4 days
C. 6 days
D. 8 days

M45. Susan performs an experiment in which a radioactive source is placed closely in front of a GM counter. The graph below shows the variation of count rate with time.
(07)



What is the half-life of the radioactive substance ?
A. 4 minutes
B. 5 minutes
C. 8 minutes
D. 10 minutes

M46. Some dangerous substances are stored in a metal container inside a wooden box as
(07) shown in the figure. What metal should be used for the container and what type of substance is stored ?

	Metal used	Type of substance stored
A.	Iron	Radioactive
B.	Iron	Flammable
C.	Lead	Radioactive
D.	Lead	Flammable

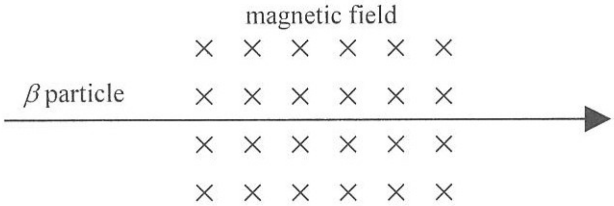
M47. Which of the following descriptions about the half-life of a radioactive substance in a sample is correct ?
(08) A. It is equal to half of the time for all the radioactive nuclei of the substance to decay.
B. It is equal to half of the time for a radioactive nucleus of the substance to decay.
C. It is equal to the time for the sample to reduce its mass by half.
D. It is equal to the time for half of the radioactive nuclei of the substance to decay.

M48. Which of the following actions will maximise a person's exposure to radiation ?
(08) A. Using a GM tube and counter to measure the background radiation in laboratory.
B. Eating food that has been sterilised by exposure to gamma radiation.
C. Listening to radio.
D. Going for a flight to a distant place in a high-flying aeroplane.

M49. Which of the following statements about β particles is correct ?
(08) A. β particles carry positive charge.
B. β particles can be deflected by a magnetic field.
C. β particles cannot be deflected by an electric field.
D. β particles can be stopped by a sheet of paper.

M50. The half-life of a radioactive sample is 15 hours. The initial count rate recorded is 1000 counts per minute. After 15 hours,
(09) the count rate recorded becomes 528 counts per minute. What is the background count rate ? (Measured in counts per minute.)
A. 25
B. 28
C. 50
D. 56

M51.
(10)



In the above figure, a β particle enters a region with a magnetic field pointing into paper and an electric field of unknown direction. The β particle has no deflection. What is the direction of the electric field ?

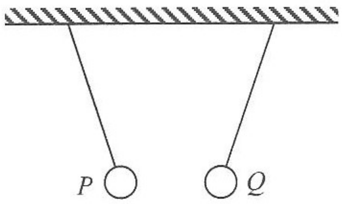
A. ←

B. →

C. ↑

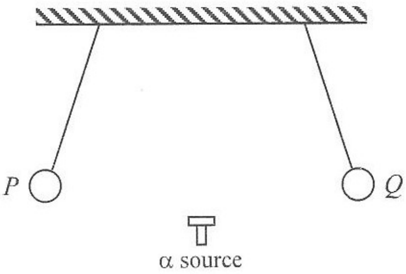
D. ↓

M52.
(10)

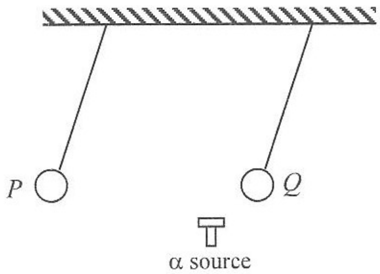


In the figure above, two charged metal balls P and Q are hung by insulating threads. P is positively charged while Q is negatively charged. An α source is put near the balls without touching them. Which of the following figures shows the situation after a period of time ?

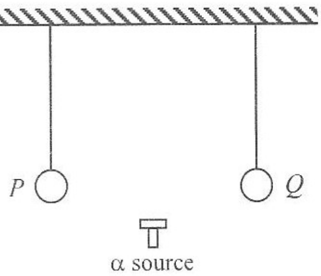
A.



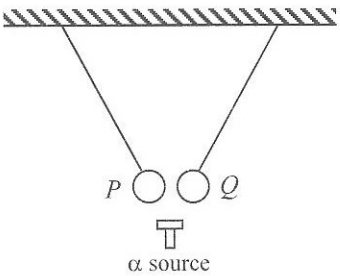
B.



C.



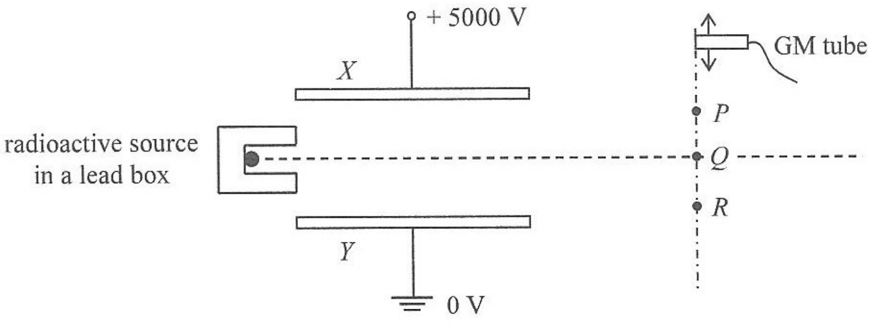
D.



M53. The initial activity of a sample of radioisotope is 960 Bq. Its activity drops to 240 Bq in 2 minutes. How much more time
(10) would be required for its activity to become 30 Bq ?

A. 2 minutes
B. 3 minutes
C. 4 minutes
D. 5 minutes

M54.
(11)



The figure shows a radioactive source placed near two parallel metal plates X and Y that are connected to a power supply. When a GM tube is moved along the dotted line (– · – · –), the count rate shows a significant increase at P and Q respectively. Which of the following statements is correct when a magnetic field pointing out of paper is applied between X and Y ?

A. The count rate at P decreases and the count rate at Q remains the same.
B. The count rates at P and Q remain the same.
C. The count rate at P decreases and the count rates at Q and R increase.
D. The count rates at P, Q and R are equal.

M55. Which of the following statements about α, β and γ radiations is **incorrect** ?
(11) A. Only γ radiation can travel through a vacuum.
B. α radiation can be stopped by an aluminium plate of 5 mm thick.
C. β particles are fast moving electrons.
D. γ radiation can blacken a photographic film.

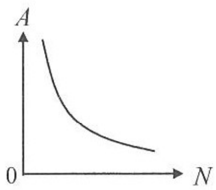
M56. A radioactive source is put in front of a GM tube. The initial count rate is 1050 counts per minute. It is known that the (11) half-life of the source is 4 hours and the background count rate is 50 counts per minute. What is the most likely count rate (in counts per minute) after 8 hours ?
A. 50
B. 125
C. 250
D. 300

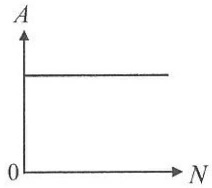
Part C :

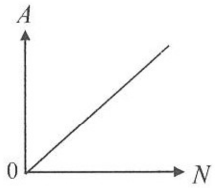
The following questions marked with [ ] are the past HKAL questions.

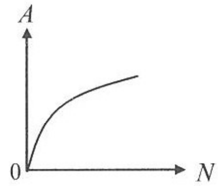
The number inside the brackets represents the year of the examination.

M57. Which of the graphs below correctly represents the variation of the activity A of a radioactive sample with the number N of [80] undecayed nuclei in the sample ?

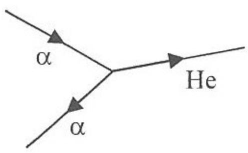
A.


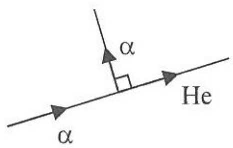
B.


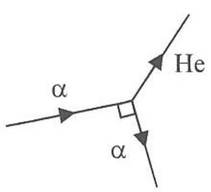
C.


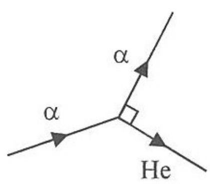
D.


M58. An alpha particle collides with a stationary helium nucleus (He) in a cloud chamber. Which of the following diagrams best [84] represents the most probable set of tracks ?

A.


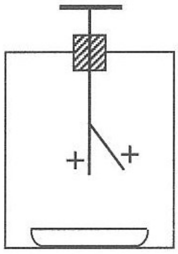
B.


C.


D.


M59. Proactinium extracted from a solution of uranyl nitrate decays with a half-life of 72 s. The value of the decay constant is
[85] A. 9.6×10^{-3} s.
B. 9.6×10^{-3} s^{-1}.
C. 0.014 s^{-1}.
D. 49.9 s.

M60.
[85]



A dish containing a strong α-source is placed inside a gold leaf electroscope containing dry air. If the gold-leaf is originally positively charged, what will happen to it after a few minutes ?

A. It will increase in divergence.
B. It will increase in divergence and then decrease.
C. It will collapse.
D. It will collapse and then re-diverge.

M61. [88] An α-source originally consisted entirely of the element polonium. After the emission of a single α-particle, each polonium atom becomes an atom of lead. At the end of two years, the source was found to contain 98% lead and 2% polonium. At the end of one year, the sample would have had the approximate composition :

A. 25% lead, 75% polonium.
B. 50% lead, 50% polonium.
C. 75% lead, 25% polonium.
D. 86% lead, 14% polonium.

M62. [90] A radioactive source is placed in front of a GM tube connected to a counter. Various absorbers are placed between the source and the GM tube and the count-rate recorded. The following results were obtained :

Absorber	Counts per minute
no absorber	711
a sheet of paper	508
5 mm thick aluminium sheet	493
25 mm thick lead block	218

It can be deduced from these results that the radiation(s) emitted by the source is/are

A. α and γ rays only
B. β and γ rays only
C. α rays only
D. β rays only

M63. [92] A radioactive source consists of a mixture of two radioisotopes P and Q. P has a half-life of 1 hour and Q has a half-life of 2 hours. Both P and Q have stable daughter nuclei. The initial corrected count rate due to the mixture recorded by a counter is 600 counts per min. After 4 hours the counter registers the corrected count rate of 60 counts per min. What was the initial count rate due to P only ?

A. 200 counts per min.
B. 360 counts per min.
C. 400 counts per min.
D. 480 counts per min.

M64. [94] A detector is used for monitoring an α-source and a reading of 120 units is observed. After a time equal to the half-life of the α-source, the reading has fallen to 64 units. If a 5 mm thick lead sheet is inserted between the α-source and the detector, the reading would probably be

A. 0 unit
B. 4 units
C. 8 units
D. 16 units

M65. A counter is placed near a very weak radioactive source which has a half-life of 1 hour. The counter registers 100 counts per
[96] min at noon and 80 counts per min at 1 p.m. The expected count rate in counts per min at 3 p.m. on the same day is

A. 50
B. 55
C. 60
D. 65

M66. The activity of a sample of radioactive isotopes decreases to $\frac{1}{3}$ of its initial value in 12 s. How much more time would be
[98] required for the activity to decrease to $\frac{1}{9}$ of its initial value ?

A. 4 s
B. 8 s
C. 12 s
D. 16 s

M67. A GM counter is placed close to and in front of a radioactive source which emits both α and γ radiation. The count rate
[00] recorded is 500 counts per minute while the background count rate is 50 counts per minute. Three different materials are placed **in turn** between the source and the counter. The following results are obtained.

Material	Recorded count rate / counts per minute
(Nil)	500
Cardboard	x
1 mm of aluminium	y
5 mm of lead	z

Which of the following is a suitable set of values for x, y and z ?

	x	y	z
A.	350	350	150
B.	350	150	50
C.	350	150	0
D.	150	150	50

M68. The table below gives the corrected count rate (in counts per minute) from three samples of radioactive isotopes at three
[01] different times.

Isotopes	0 min	20 min	40 min
X	480	243	119
Y	135	32	9
Z	168	118	93

The above data show that

(1) X produces the most penetrating radiation.
(2) Y has the largest decay constant.
(3) Z has the longest half-life.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M69. The activity of a radioactive sample was 70 Bq at time t = 5 minutes and 49 Bq at t = 10 minutes. Deduce its activity at
[01] time t = 0.

A. 112 Bq
B. 100 Bq
C. 95 Bq
D. 91 Bq

M70. A nuclide in radioactive sample has a constant chance of 10^{-6} to decay in one second. What is the **approximate** half-life of
[03] the sample ?

A. 1 day
B. 1 week
C. 1 month
D. 1 year

M71. The activity of a freshly prepared sample of ^{60}Co is 1.0×10^6 Bq. The half-life of ^{60}Co is 5.3 years. Estimate the number of
[04] ^{60}Co nuclei in the sample that decay in the first day.

A. 5.2×10^2
B. 3.2×10^8
C. 8.6×10^{10}
D. It cannot be estimated as the initial number of nuclei in the sample is not given.

M72. On which of the following does the activity of a radioactive source depend ?
[05]
(1) the number of active nuclei in the source
(2) the half-life of the source
(3) the nature of the nuclear radiation emitted by the source

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M73. Some typical radiation doses are tabulated as follows :
[06]

	Radiation dose
Watching television	0.005 mSv / hr for watching every day in a year
Flying in an aircraft	0.001 mSv / hr
X-ray check	0.020 mSv each time

Arrange the following in ascending order of total radiation dose in one year.

(1) Watching television for 4 hours every day
(2) Travelling on an aircraft for 10 hours every month
(3) Taking X-ray check every 6 months

A. (1), (2), (3)
B. (2), (1), (3)
C. (1), (3), (2)
D. (3), (1), (2)

M74. Which of the following gives the correct meaning of the decay constant of a radioactive substance ?
[06] A. It is the rate of disintegrations of the substance.
B. It is the number of disintegrations of the substance occurring on one half-life of the substance.
C. It is the fraction of the active nuclei present that decay in one second.
D. It is equal to the reciprocal of the half-life of the substance.

M75. A radioactive source consists of 64×10^{12} atoms of nuclide P of half-life 2 days. Another source consists of 8×10^{12} atoms
[07] of nuclide Q of half-life 3 days. After how long will the number of active nuclei in the two sources be equal ?
(Assume that the daughter nuclides of both P and Q are stable.)
A. 6 days
B. 9 days
C. 12 days
D. 18 days

M76. Radioactive nuclides X and Y have half-lives 2 hours and 4 hours respectively. The decay of both nuclides gives stable
[11] daughters. Initially samples P and Q contain equal number of atoms of nuclide X and nuclide Y respectively. Which statements are correct ?
(1) The initial activity of sample P is higher than that of sample Q.
(2) After 8 hours, sample P contains more active nuclei than sample Q.
(3) After 8 hours, the chance of a nucleus of X in sample P decaying in the next minute is greater than that of a nucleus of Y in sample Q.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M77. The activity of a radioisotope is 250 Bq at time $t = 0$ and 54 Bq at $t = 30$ min. Estimate its activity at $t = 10$ min.
[12] A. 130 Bq
B. 150 Bq
C. 185 Bq
D. It cannot be found as its half-life is not given.

M78. Arrange the following lengths in ascending order of magnitudes.
[13] (1) range of α-particles in air
(2) grating spacing of a typical diffraction grating in a school laboratory
(3) wavelength of ultra-violet radiation

A. (1), (2), (3)
B. (1), (3), (2)
C. (3), (1), (2)
D. (3), (2), (1)

M79. The initial activity of two different radioactive sources, X and Y, are the same. Both X and Y decay to stable daughter nuclei.
[13] The ratio of the activity of X to that of Y after 12 hours is 4 : 1. If X has a half-life of 6 hours, what is the half-life of Y ?
A. 1.5 hours
B. 2 hours
C. 3 hours
D. 12 hours

Answers

1. D	11. D	21. B	31. A	41. C	51. D	61. D	71. C
2. C	12. D	22. C	32. A	42. C	52. C	62. A	72. C
3. C	13. A	23. B	33. D	43. B	53. B	63. D	73. C
4. B	14. D	24. B	34. C	44. C	54. A	64. C	74. C
5. C	15. C	25. D	35. D	45. A	55. A	65. D	75. D
6. C	16. D	26. D	36. D	46. C	56. D	66. C	76. B
7. B	17. C	27. D	37. D	47. D	57. C	67. A	77. B
8. A	18. B	28. D	38. D	48. D	58. D	68. D	78. D
9. A	19. C	29. C	39. C	49. B	59. B	69. B	79. C
10. B	20. C	30. D	40. B	50. D	60. C	70. B	

Solution

1. D

× (1) The nature or type of radiation (α, β, γ) emitted would not affect or relate to the activity of the source.

✓ (2) The activity A is proportional to the decay constant k, which is related by the half-life.

✓ (3) The activity A is proportional to the number of active (undecayed) nuclei N.

2. C

After inserting the paper, the count rate is approximately unchanged, thus the source does not emit α.

After inserting the 5 mm Al, the count rate drops significantly, thus the source emits β.

After inserting the lead, the count rate drops significantly, thus the source emits γ.

3. C

✓ (1) The mass of an α particle is the mass of a helium nucleus but the mass of a β particle is nearly zero.

× (2) The penetrating power of α is weaker than β.

✓ (3) α particles can ionize the air, the ions then discharge the charged metal sphere.

4. B

× A. Since there is no count rate recorded at positions above X, the source may or may not emit α radiations.

✓ B. Since the count rate at Y is greater than X, there must be some radiation deflected downwards to reach Y. By Left hand rule, the downward magnetic force should act on negative particles, that is, β radiations.

× C. The source may or may not emit γ radiation, as the count rate at X may consist of γ and background or background only

× D. The source may emit γ radiation, thus the count rate of 101 cpm at X may be due to γ and background.

The following list of formulae may be found useful :

Law of radioactive decay	$N = N_0 e^{-kt}$
Half-life and decay constant	$t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$

Part A :

The following questions marked with { } are the past DSE examination questions.

The question marked with {PP} is the Practice Paper question.

The number inside the brackets represents the year of the DSE examination.

Q1. {PP} The decay of radioactive isotope protactinium-238 (^{238}Pa) has a half-life of approximately 136 s. A sample of ^{238}Pa is put in front of a GM tube and the initial count rate is 1000 counts per minute. The background count rate is 50 counts per minute.

(a) It is known that the decay of ^{238}Pa does not emit γ radiation. Suggest a simple test to verify the radiation from ^{238}Pa is β radiation but not α radiation. (3 marks)

(b) Estimate the decay constant of ^{238}Pa. (1 mark)

(c) Hence, or otherwise, estimate the time taken for the count rate to drop to 250 counts per minute. (3 marks)

Q2. {14} *Voyager I* is a space probe designed by NASA to operate for over ten years in space. It was equipped with a radioisotope thermoelectric generator (RTG) which can convert the energy released from the decay of a radioactive source into electrical power. *Voyage I* operates with a plutonium-238 radioactive source that undergoes α-decay.

(a) The plutonium-238 source is sealed inside a thin metallic casing of the RTG. The photo shows a NASA staff handling the RTG with his bare hands. Explain why it is fine for it to be handled by the staff in this way. (1 mark)

When *Voyager I* was launched, the number of plutonium-238 atoms in the source was 3.2×10^{25}.

Given : half-life of plutonium-238 = 87.74 years.

Take 1 year = 3.16×10^{7} s.

(b) (i) Find the activity, in Bq, of the plutonium source at the time of launch. (3 marks)

(ii) When a plutonium-238 atom decays, it releases 5.5 MeV of energy. Estimate the power, in kW, delivered by the source at the time of launch. (2 marks)

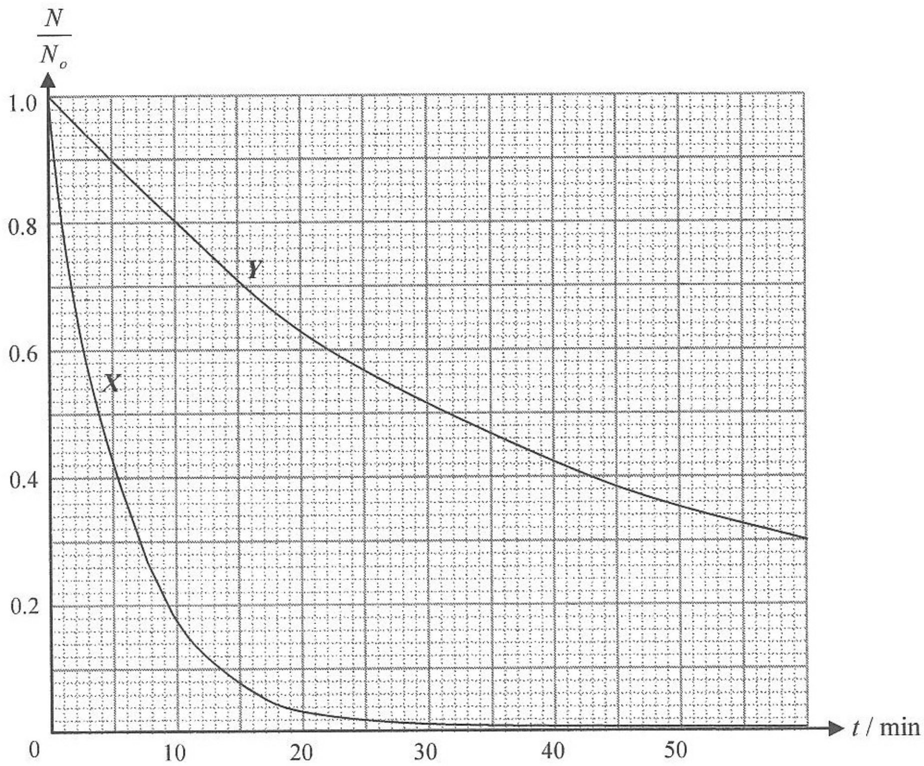
(iii) The RTG of *Voyage I* is still in operation as *Voyage I* just left the solar system in September 2013 after it was launched 36 years ago. Estimate the corresponding power delivered by the plutonium source, expressed in percentage of the power delivered at the time of launch. (2 marks)

Part B :

The following questions marked with ( ) are the past HKCE questions.

The number inside the brackets represents the year of the examination.

Q3.
(82)



The above figure show the decay curves of two radioactive elements X and Y both emitting β-particles. N_o is the number of radioactive atoms present at time $t = 0$ and N is the number at the end of t minutes.

(a) What are the half-lives of X and Y ? (2 marks)

(b) A mixture of X and Y is placed in front of a Geiger counter. Initially, they have the same number of radioactive atoms. Which of the two, X or Y, will be mainly responsible for the reading shown on the Geiger counter during the first four minutes ? Estimate the fraction of the total number of counts due to that element. (5 marks)

Q4. (83) The activity from a sample of Radium is measured at two-day intervals. The readings are tabulated below :

Time / days	0	2	4	6	8	10
Activity / Bq	100	68	47	32	22	15

(a) Plot the decay graph below to show the activity against time. (4 marks)

(b) From the graph, find (2 marks)

(i) the activity of the sample after 5 days, and

(ii) the half-life of the sample.

Q5. A Geiger-Muller counter is placed on a bench.
(83)

(a) Explain why the counter registers a reading even when no radioactive source is placed nearby. (1 mark)

____

____

(b) When a radioactive source is placed near the counter, the counter registers 520, 510 and 514 counts per minute in the first three consecutive minutes. Explain why the three readings differ from each other ? (2 marks)

____

____

(c) When a piece of paper is placed between the source in (ii) and the counter, the counter registers 540, 510 and 512 counts per minute in the first three consecutive minutes. However, when the paper is replaced by an aluminium sheet, the counts are reduced to 7, 9 and 8 respectively.

What type(s) of radiation (α, β or γ) is/are being emitted by the source ? Give a reason for your answer. (4 marks)

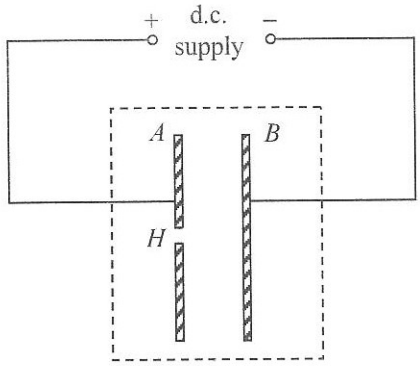
____

____

____

____

Q6. Two parallel metal plates A and B are placed in a vacuum chamber as shown in the figure below. They are connected to a
(84) d.c. supply. A hole H is drilled in plate A. A particle P passes through hole H and accelerates towards plate B.



(a) What is the sign of the charge carried by P ? (1 mark)

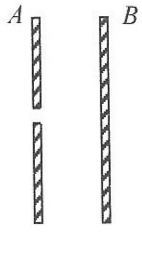
____

(b) The particle P is emitted from a radioactive source which undergoes α-, β- and γ-decay simultaneously.

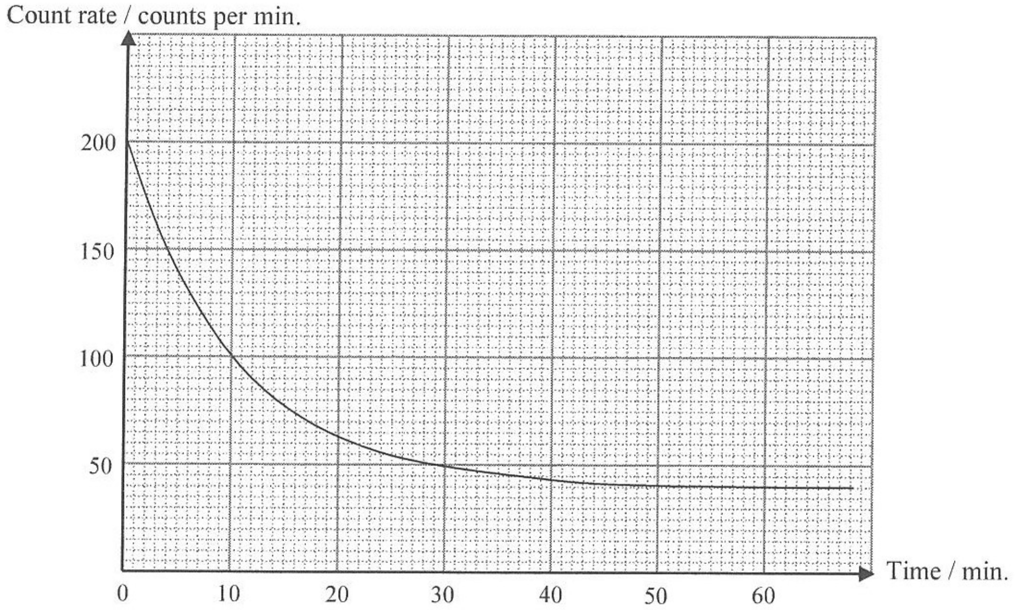
(i) What kind of particle (α, β or γ) should P be ? (1 mark)

____

(ii) Draw a diagram to show how to prevent the other two kinds of particles from reaching H. Show the tracks of the particles in your diagram. (4 marks)



Q7.
(86)



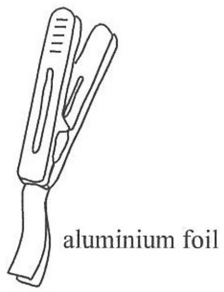
The figure above shows the variation of count rate of a radioactive source measured by a GM counter with time.

(a) Find from the figure, the background count rate of the room. (2 marks)

(b) Find the count rate due only to the radioactive source at time 0. (2 marks)

(c) Determine the half-life of the radioactive source. (2 marks)

Q8.
(87)
The below figure shows a pair of positively charged aluminium foils.



(a) When the aluminium foils are placed near an α source, the foils are found to gradually collapse. Briefly explain why. (2 marks)

(b) Would the foils collapse faster or slower if the foils were placed near a γ source instead of an α source ? Explain briefly. (2 marks)

Q9. (89) A student measures the count rate of a source of half-life of 25 min using a GM counter in a room with very little background radiation. Initially the reading of the GM counter shows 560 counts per second.

(a) What should be the count rate of the source after 25 minutes ? (2 marks)

(b) Plot on the graph below the theoretical decay curve of the radioactive source for the first 100 minutes. (4 marks)

(c) The actual readings of the GM counter are as follows:

Time / min.	0	50	75	100
Count rate / counts per second	560	154	70	31

Do you think that the GM counter is working properly ? Explain briefly. (3 marks)

Q10. (a) What is the major source of background radiation

(89)

(i) at an altitude of 10000 m above sea-level ;

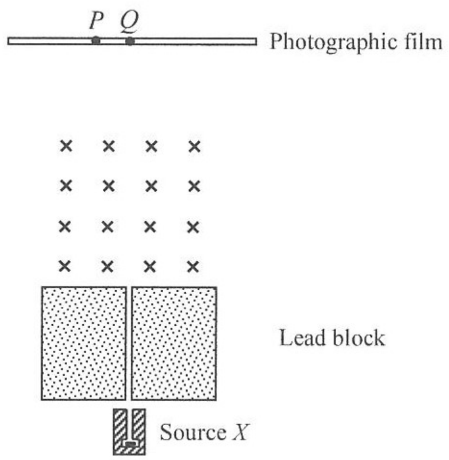
(ii) inside the Lion Rock Tunnel ;

(iii) in an underground coal mine ? (3 marks)

(b) It is reported that the background radiation in a concrete building is higher than that in a wooden hut. A person thus decides to move to a wooden hut. Do you think that his decision is wise ? Explain briefly. (3 marks)

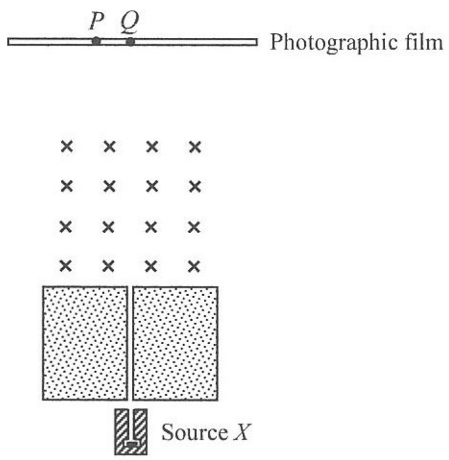
Q11.

(90)



The above figure shows the set-up of an experiment carried out in an evacuated chamber to study the radiation from a radioactive source X. X emits α, β and γ radiation. A magnetic field (pointing into the paper) is applied. The photographic film is developed and marks in the positions P and Q are observed.

(a) In the figure below, sketch and label the paths of the α, β and γ radiation emitted from the source X. (5 marks)



Q11. (b) Explain briefly

(i) why the experiment is carried out in an evacuated chamber. (2 marks)

(ii) the use of the lead block in the set-up. (2 marks)

(c) If a piece of cardboard is placed between the source and the lead block, what type(s) of radiation would be recorded on the photographic film ? (2 marks)

(d) Suggest an alternative detector to replace the photographic film in the experiment. (2 marks)

Q12. A cloud chamber is used to observe the tracks of α-particles.
(93)

(a) Describe the tracks of α-particles in the cloud chamber. (2 marks)

(b) An α-particle collides with a helium nucleus to form a fork track. What is the angle of the fork track and what does this angle indicate ? (2 marks)

Q13. In a school laboratory, the background count rate recorded by a GM counter is 100 counts per minute.

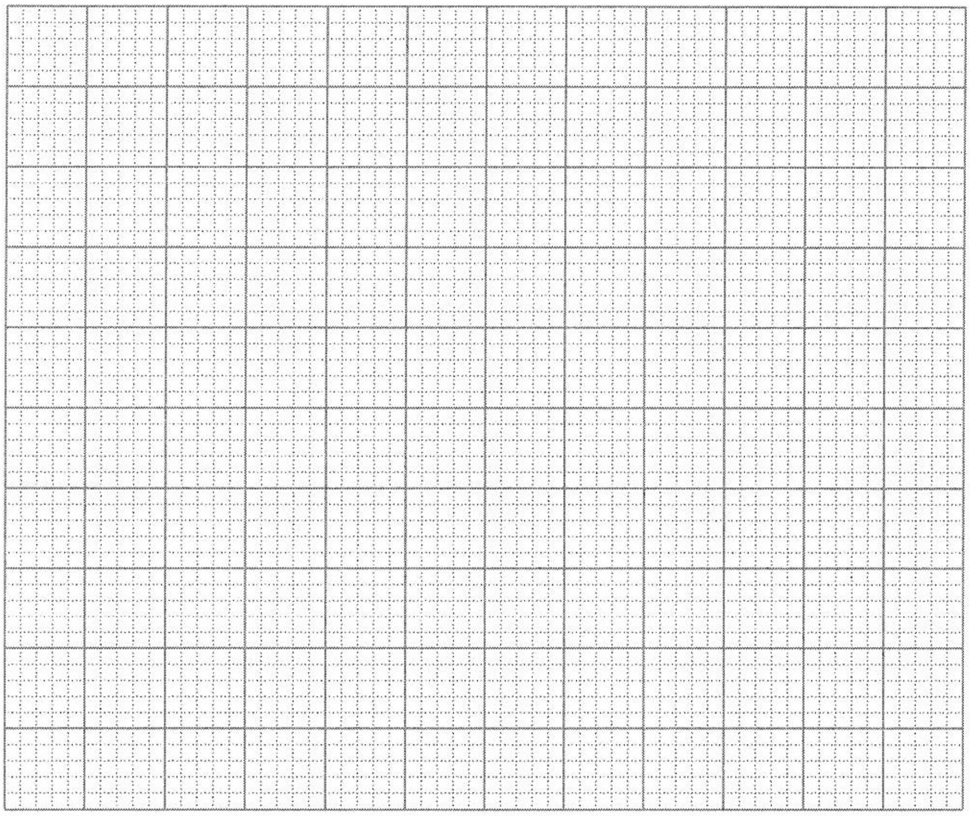
(95) (a) The counter is placed close in front of a radioactive source P. The following results are obtained :

Time t / hour	0	20	40	60	80	100	120
Recorded count rate / counts per minute	620	400	270	199	157	133	118

(i) Find the corrected count rate at $t = 0$. (1 mark)

____

(ii) Plot the graph of the corrected count rate against time on the graph below. (5 marks)



(iii) Hence find the half-life of the source. (1 mark)

____

(b) To find out the kind(s) of radiation emitted by P, sheets of difference materials are placed in turn between P and the counter. The following results are obtained :

Material	Recorded count rate / counts per minute
–	620
Paper	623
5 mm Aluminium	98
5 mm Lead	101

Explain how the result shows that P emits β radiation only and it does not emit α or γ radiation. (4 marks)

____

____

____

Q13. (c) If the experiment in (b) is repeated with another source Q which emits both α and γ radiation, a different set of readings would be obtained, as shown in the below table.

Material	Recorded count rate / counts per minute
–	750
Paper	x
5 mm Aluminium	y
5 mm Lead	z

From the following list, choose suitable values for x, y and z :

0, 100, 195, 540, 750

(Note : A reading may be used more than once.) (3 marks)

Q14. (99) To investigate the kind(s) of radiation emitted by a radioactive source, a Geiger-Muller counter is placed close in front of the source and sheets of different absorbers are placed in turn between the source and the counter. Three readings are taken at one-minute intervals for each absorber. The following results are obtained :

Absorber	Recorded count rate / counts per minute		
	1st reading	2nd reading	3rd reading
–	700	710	693
Paper	702	703	701
1 mm Aluminium	313	320	317
5 mm Lead	98	101	100

The background count rate recorded by the counter is 100 counts per minute.

(a) Explain why the three readings for each absorber are not identical. (1 mark)

(b) Explain how the above results show that the source emits β radiation only and it does not emit α and γ radiation. (4 marks)

Q15.
(01)

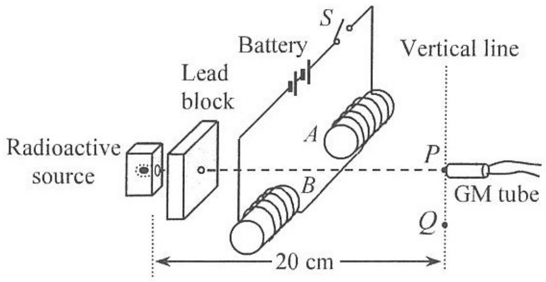


Figure 1

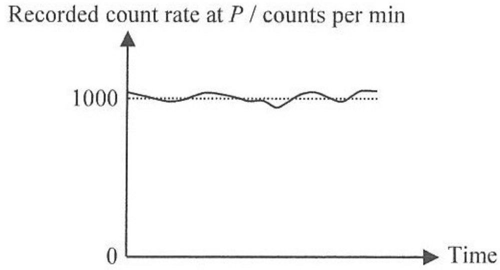


Figure 2

Figure 1 shows a set-up used to study the radiation from a radioactive source. A GM tube is placed at position P, which is at 20 cm from the source. Two coils A and B connected to a battery and a switch S are placed between the source and the GM tube as shown. Initially, S is open and the variation of the count rate recorded by the GM tube with time is shown in Figure 2.

(a) Explain why the count rate shown in Figure 2 is **not** due to α particles, no matter what kinds of radiation are emitted by the source. (2 marks)

(b) Now switch S is closed. The GM tube is placed at positions P and Q in turn (see Figure 1) and the count rates recorded are shown in Figure 3 and 4 respectively. When the GM tube is placed at any point vertically above P, an average count rate of 100 counts per minute is recorded at each point.

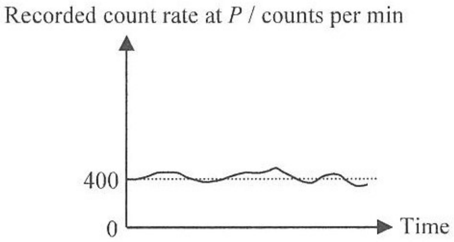


Figure 3

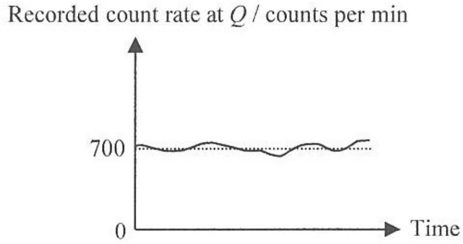


Figure 4

(i) State the direction of the magnetic field formed between coils A and B. (1 mark)

(ii) What kind of radiation is recorded when the GM tube is held at any point vertically above P ? Explain your answer. (3 marks)

(iii) What conclusion about the radiation emitted by the source can you draw from Figure 3 and Figure 4? Explain your answer. (4 marks)

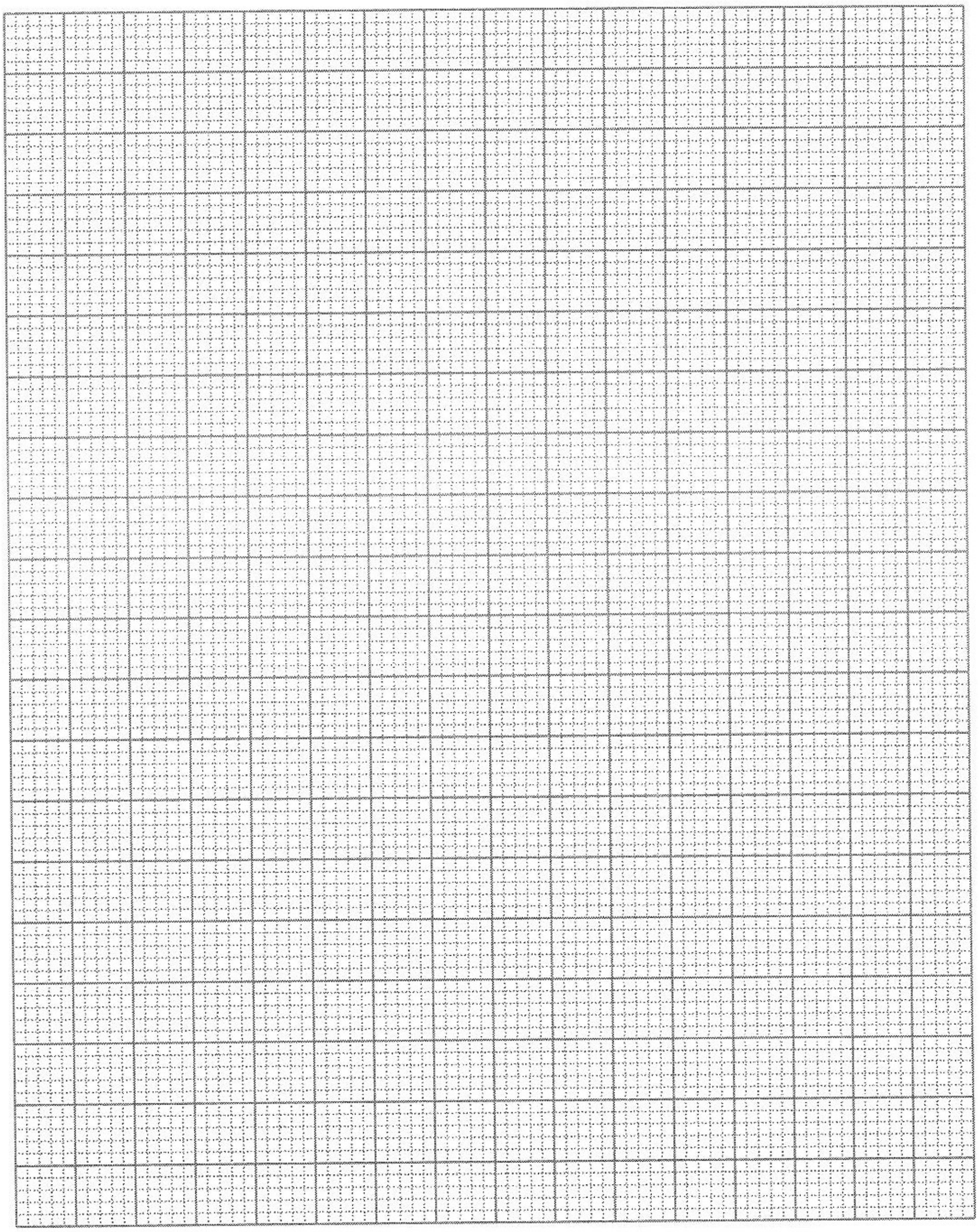
(iv) Explain why the sum of the average count rates recorded in Figure 3 and Figure 4 is greater than that recorded in Figure 2. (2 marks)

(c) The above experiment **cannot** determine whether α particles are emitted by the source. Suggest a method for finding out the answer. (2 marks)

Q16. Carol performs an experiment to measure the half-life of a radioactive source. She places a Geiger-Muller tube in front of the
(05) source and the following results are obtained :

Time t / hour	0	10	20	30	40	50	60	70
Count rate / counts per minute	400	225	154	119	107	105	100	102

(a) Plot a graph of the count rate against time in the Figure below. (4 marks)



(b) Estimate the background count rate. (1 mark)

(c) Estimate the corrected count rate at $t = 0$. Hence, or otherwise, estimate the half-life of the source. (2 marks)

Q17. (06) Workers of nuclear plants are required to wear film badges (see Figure 1) to monitor their exposure to radiation. Inside the film badge, an opaque plastic bag is wrapped around a sheet of photographic film. Aluminium and lead sheets are also placed inside the badge (see Figure 2) so that the types of incoming radiation can be distinguished.

Figure 1

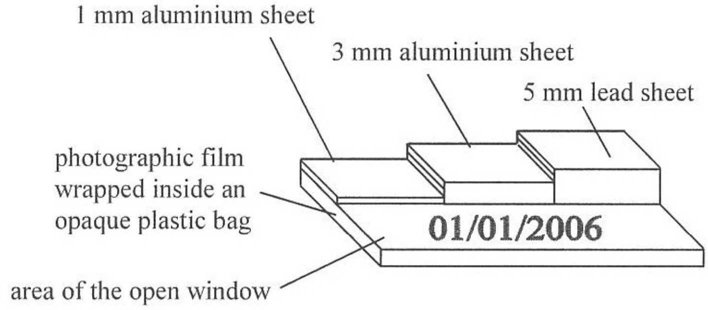


Figure 2

(a) What type(s) of radiation can be detected by the badge ? (1 mark)

(b) Why is an opaque plastic bag used to wrap the photographic film ? (1 mark)

(c) The films of three workers John, Mary and Ken were developed. The Table below shows the degrees of blackening on different regions of the films inside the badges which they wore.

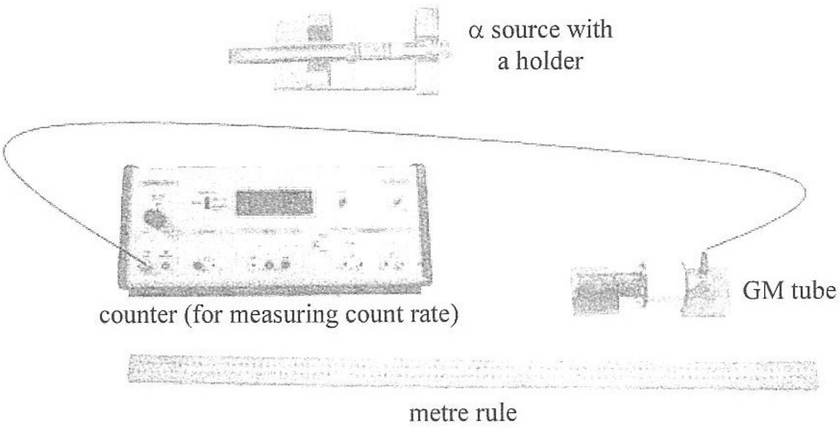
Regions on the film	Degree of blackening (0 – 5) (0 = not blackened; 5 = most blackened)		
	John	Mary	Ken
Beneath the open window	5	5	5
Beneath the 1 mm aluminium sheet	5	3	4
Beneath the 3 mm aluminium sheet	5	1	2
Beneath the 5 mm lead sheet	4	0	0

(i) Based on the results in the above Table, explain which type(s) of radiation John and Mary are definitely being exposed to respectively. (3 marks)

(ii) Give one reason why different degrees of blackening were recorded on the films of Mary and Ken. (1 mark)

(d) Suggest one hazard of exposure to ionizing radiations. (1 mark)

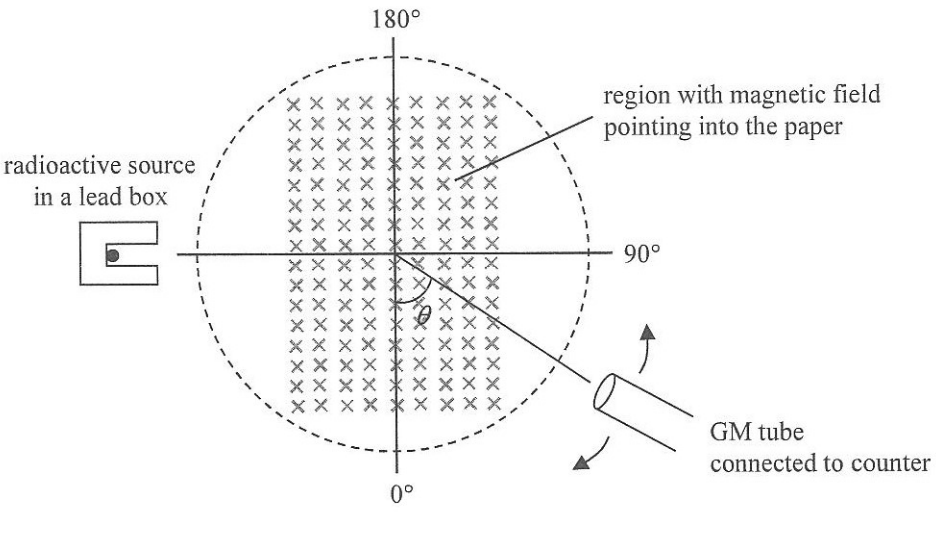
Q18. (07) In a physics lesson, a teacher uses the apparatus shown in Figure 13 to find the range of α particles in the air. Describe the procedures of the experiment. (4 marks)



Q19. (08) (a) A teacher places a radioactive source 1 cm in front of a Geiger-Muller tube (GM tube) and measures the count rate. When he inserts a piece of paper between the radioactive source and the GM tube, he finds that there is no significant change in the measured count rate. State the conclusion about the type of radiation emitted from the radioactive source. (1 mark)

The teacher then conducts another experiment to investigate the deflection of radiations inside a magnetic field as shown in Figure 1. The GM tube can be rotated from 0° to 180° around the magnetic field. Figure 2 shows the count rate recorded at different angles with or without the magnetic field.

Figure 1



Q19.

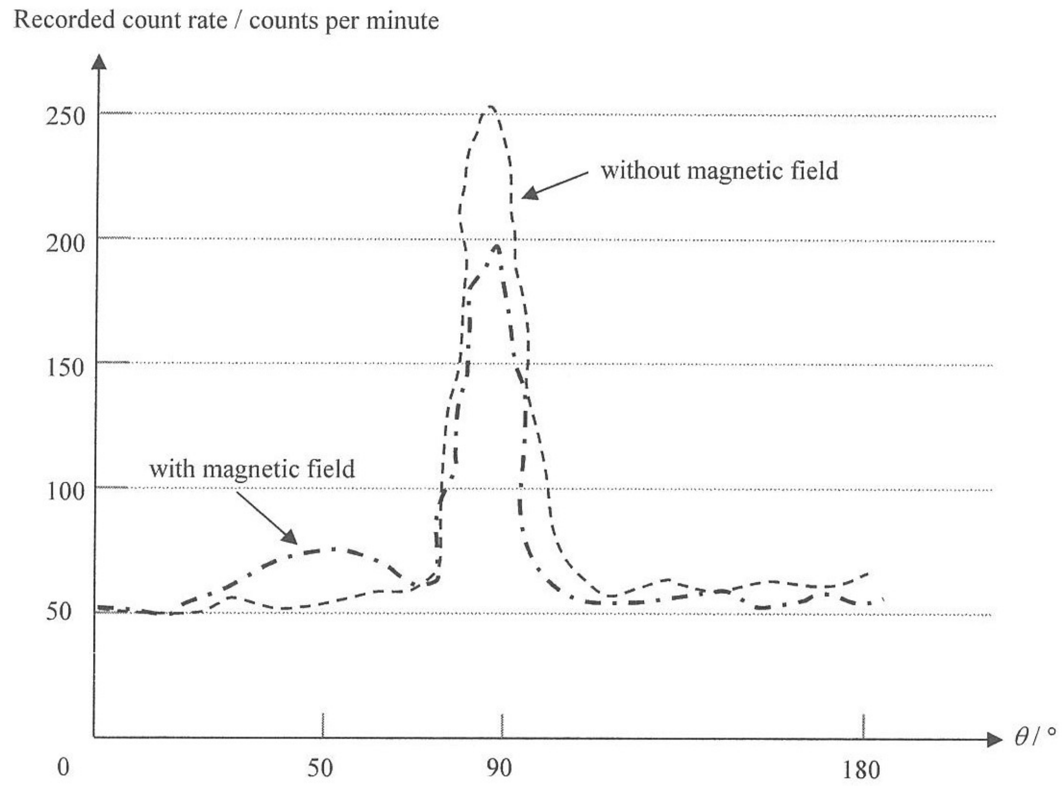


Figure 2

(b) Estimate the count rate due to the background radiation. (1 mark)

____

____

(c) Using the result in Figure 2, explain why it can be concluded that the radioactive source emits β and γ rays. (4 marks)

____

____

____

____

____

____

____

____

____

(d) Estimate the count rate due to each type of radiation at θ = 90° without the magnetic field. Write the answer in the Table below.

Type of radiation	Count rate / counts per minute
α	0
β	
γ	

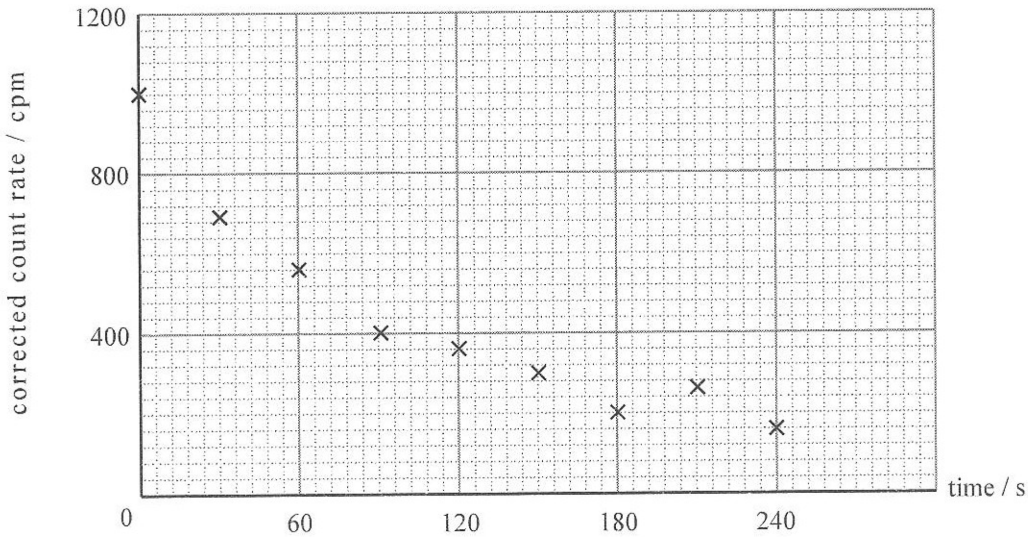
(2 marks)

Part C :

The following questions marked with [ ] are the past HKAL questions.

The number inside the brackets represents the year of the examination.

Q20.
[83]



The points plotted in the above Figure were obtained in an experiment to investigate the decay of the radioactive isotope protactinium-234 which decays by emitting β particles. Counts were taken in every 30 s interval by a GM tube and have been corrected by background radiation.

(a) A student comments that the readings have been taken carelessly because the points plotted in the above Figure do not fall on a smooth curve. Do you agree ? Explain your reasoning. (1 mark)

(b) Use the above Figure to estimate the half life of protactinium-234. (1 mark)

(c) Estimate the decay constant of protactinium-234. (1 mark)

(d) Express in words the relationship between the decay constant and the probability of an atom decaying. (1 mark)

Q21. [95] A geologist wants to find the age of a sample of rock containing potassium-40 which decays to give the stable isotope of Argon. The activity of the sample is found to be 1.6 Bq while the original activity of a similar rock having the same mass is 4.8 Bq. The half-life of potassium-40 is 1.3×10^9 years.

(a) (i) Find the decay constant of potassium-40. (2 marks)

(ii) Give the physical meaning of the decay constant of a radioactive isotope. (2 marks)

(b) Find the age of the rock sample. (2 marks)

(c) Give **two** factors that determine the activity of a radioactive source. (2 marks)